

**ACCEPTANCE DATA PACKAGE**

**NASA CONTRACT NAS8-39409**

**SXI STEPPER MOTOR/ENCODER**

**AEROFLEX P/N 16187**

**\*\*\*\*\***

**D - STRENGTH ANALYSIS**

SECTION D  
STRENGTH ANALYSIS

**STRENGTH ANALYSIS REPORT**  
**FLIGHT READINESS REVIEW (FRR)**

for

**SXI STEPPER MOTOR/ENCODER**

**Prepared by**  
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**Farmingdale New York**

for

**NASA - MSFC**

**In Accordance with MSFC-HDBK-505A**

#### **Summary:**

The strength analysis report for FRR shall include only revisions to update the strength analysis reports for the flight design configuration. Since there have been no revisions to the design configuration since the PDR and the CDR this report shall consist of re-submitting the analysis previously performed.

In addition the motors have been subjected to Sine vibration, Random vibration, and shock per the SXI specification. Both motor/encoders have passed all three tests. There was no evidence of damage to the motor/encoder and the motor/encoder performed as required by the Acceptance test procedure. No degradation was seen between the before and after performance tests. The testing verified the analysis that there were adequate safety margins with regard to structural integrity. Separate reports are available from the test facility and are apart of the FRR submittal.

**STEPPER MOTOR/ENCODER  
SOLAR X-RAY IMAGER (SXI)  
STRESS ANALYSIS  
(ARX P/N 16187)**

**March 16, 1994**

## **SXI STEPPER MOTOR/ENCODER**

### **VIBRATION STRESS ANALYSIS**

#### **EXTRACT**

An FEA stress analysis was performed on the Aeroflex design to assure that the motor will withstand the random vibration spectrum shown in Figure 11. The program used was ALGOR with updated releases to 5/21/93. The results are tabulated in Table I. Constants and values used for the analysis are listed in Table II.

The analysis focused on:

- \* ... The Housing (with special regard paid to the three mounting posts). A slug of dense material was cantilevered from the bearing mounting surface to simulate an unbalanced load on the mounting screws equaling the rotor weight. (It was necessary to use this simplified load and not use the actual rotor model so as not to exceed the disk space required for temporary storage files in the FEA processing). The housing was constrained on the inner surface of the mounting holes to simulate the insert contact area. All other volume was free to move in 6 axes (three translation and three rotation).

- \* ... The Rotor with encoder disk. The assembly was constrained on the outer bearing surface area.

- \* ... The large PC Board with tantalum shields attached in their 4 locations. The PC Board was constrained on the inner surface of the 4 mounting holes.

- \* ... The stress introduced by the shrink fit of the bearing liner in the housing. The outer housing was heated to +71C and the insert cooled to -40C. The stress was measured at 0 degrees C.

The vibration energy was applied in the x direction and in the y direction independently.

The summary of results is shown in Table I.

## **CONCLUSIONS**

The stress induced by vibration and thermal differentials were within the material linear ratings. However, the shrink fit of the bearing retainer sleeve into the housing was deemed to be too tight. It was necessary to press fit the two sections even at temperature. The fit now has a 2 tenths clearance at temperature. The stress reflected in the Figure 6 reflect this change.

The design is satisfactory and no further changes are necessary.

- \* Please note that figure displacements are highly exaggerated to make the small displacements visible.
- \* Not all stress and displacement results were plotted but they are shown in Table I

TABLE I

<u>ITEM DESCRIPTION</u>	<u>RESONANCE (Fund)</u>
1) ROTOR/ENCODER DISC	1096 Hz (rotary) 1238 Hz (X & Y)
2) HOUSING	2509 Hz
3) PC BOARD	1240 Hz

X VIBRATION

	<u>MAX STRESS (PSI)</u>	<u>MAX DISP (IN)</u>
1) ROTOR/ENCODER DISC	0.94 (ROTARY) 0.187 (X)	9.8E-8 1.7E-8
2) HOUSING	211	7.9E-5
3) PC BOARD	11.9	6.4E-6

Y VIBRATION

1) ROTOR/ENCODER DISC	0.0012 (ROTARY) 1442 (Y)	1.2E-10 1.3E-4
2) HOUSING	1.2	4.5E-7
3) PC BOARD	11.4	6.4e-6

TABLE II

<u>MATERIAL</u>	<u>DENSITY</u>	<u>YOUNGS MOD</u>	<u>LIN EXP</u>
ALUMINUM	0.11 LBS/IN <sup>3</sup>	10E6 PSI	23.4E-6 IN/IN/C
STEEL	0.29	29E6	10.6E-6
BeCu	0.298	18.5E6	N/A
G10 EPOXY	0.065	22E5	N/A
TANTALUM	0.6	27E6	N/A
SIM WGT (HSG)	5.5	29E6	N/A

FIGURE 2, 8#9

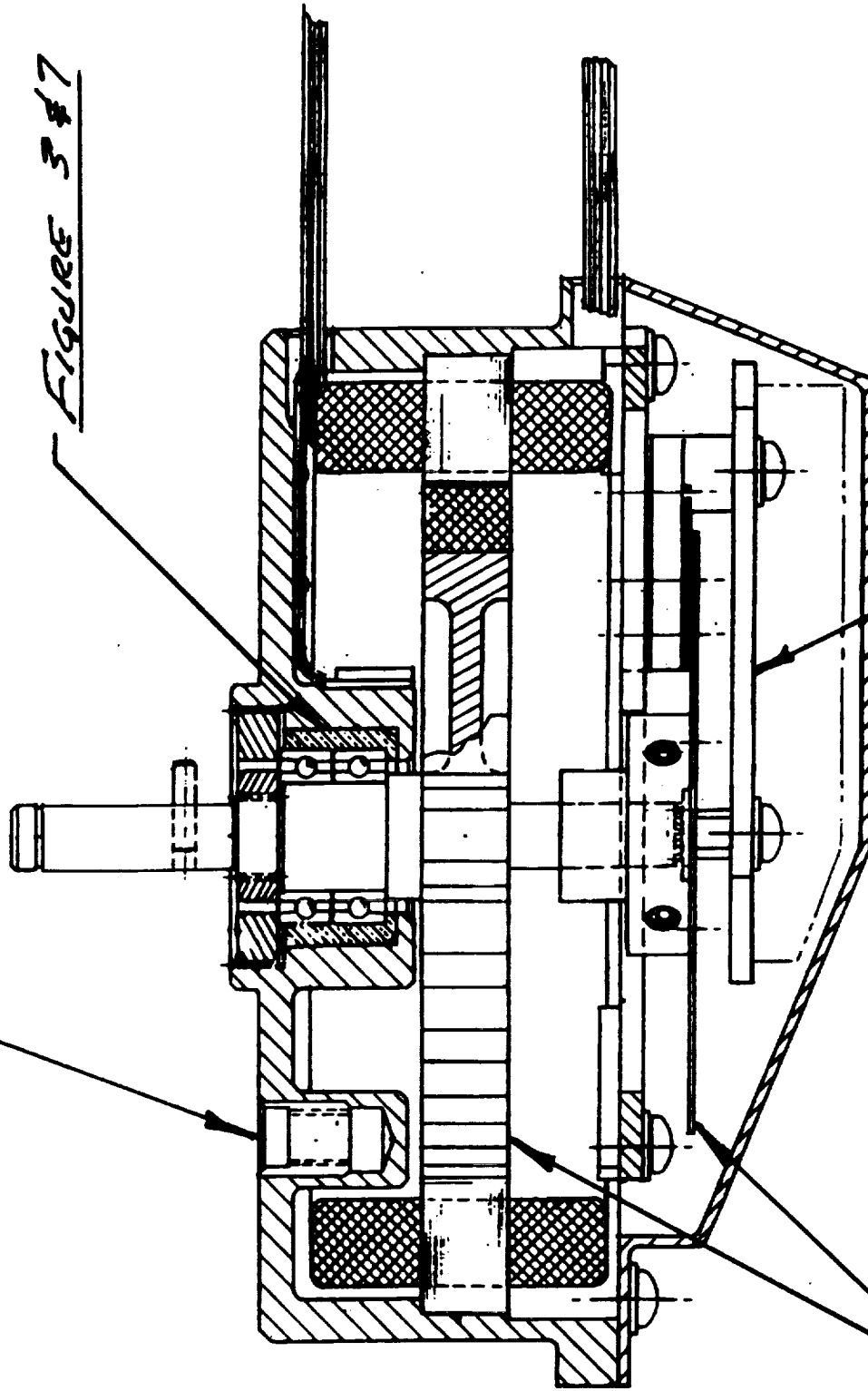


FIGURE 3#7

FIGURE 1, 5#6

FIGURE 4#10

Alorae/Emoore  
(ARX P/W 16/87)

ROTOR/ENCODER DIS. SHAFT ASSEMBLY

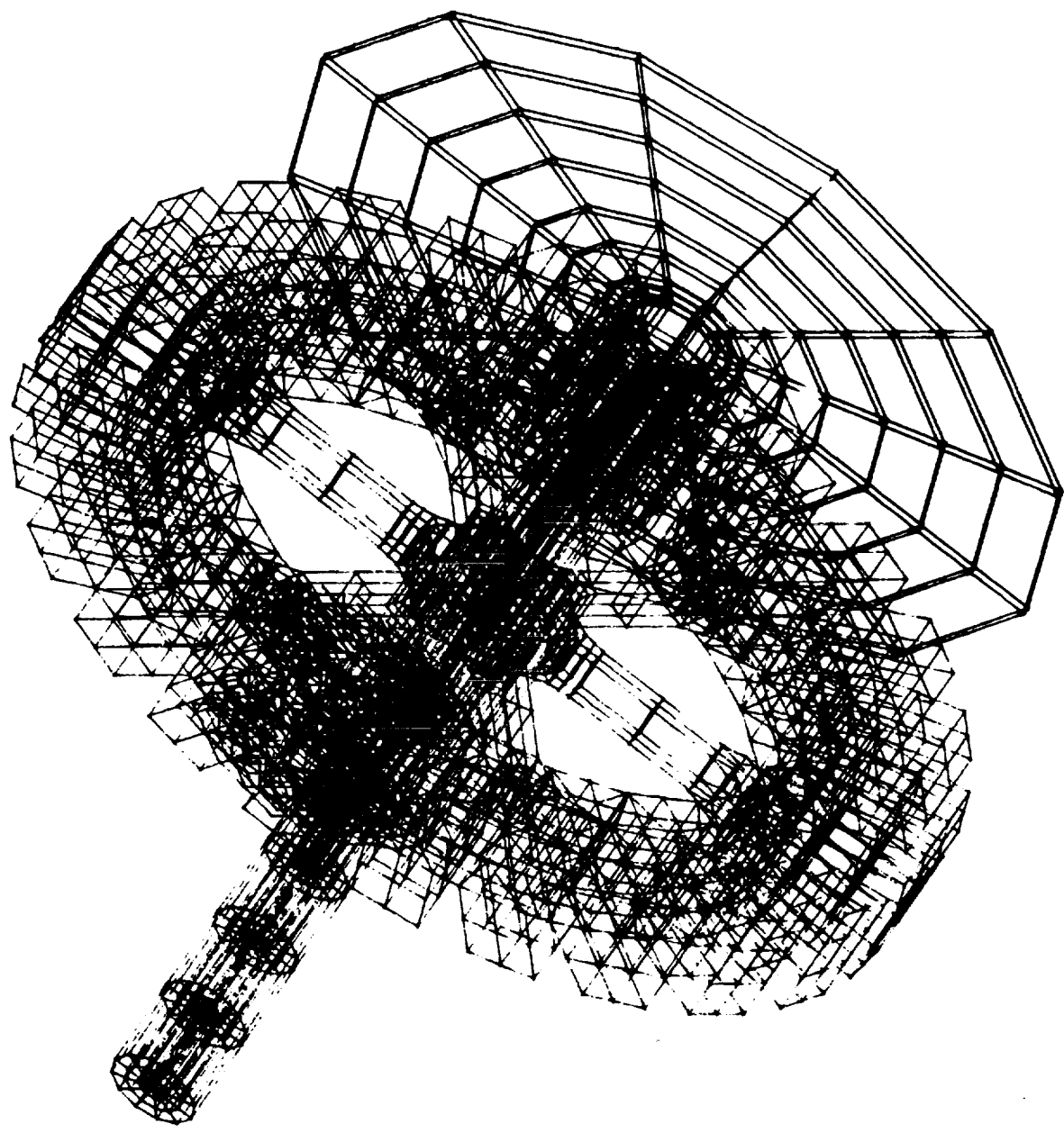


FIGURE I

# HOUSING ASSEMBLY

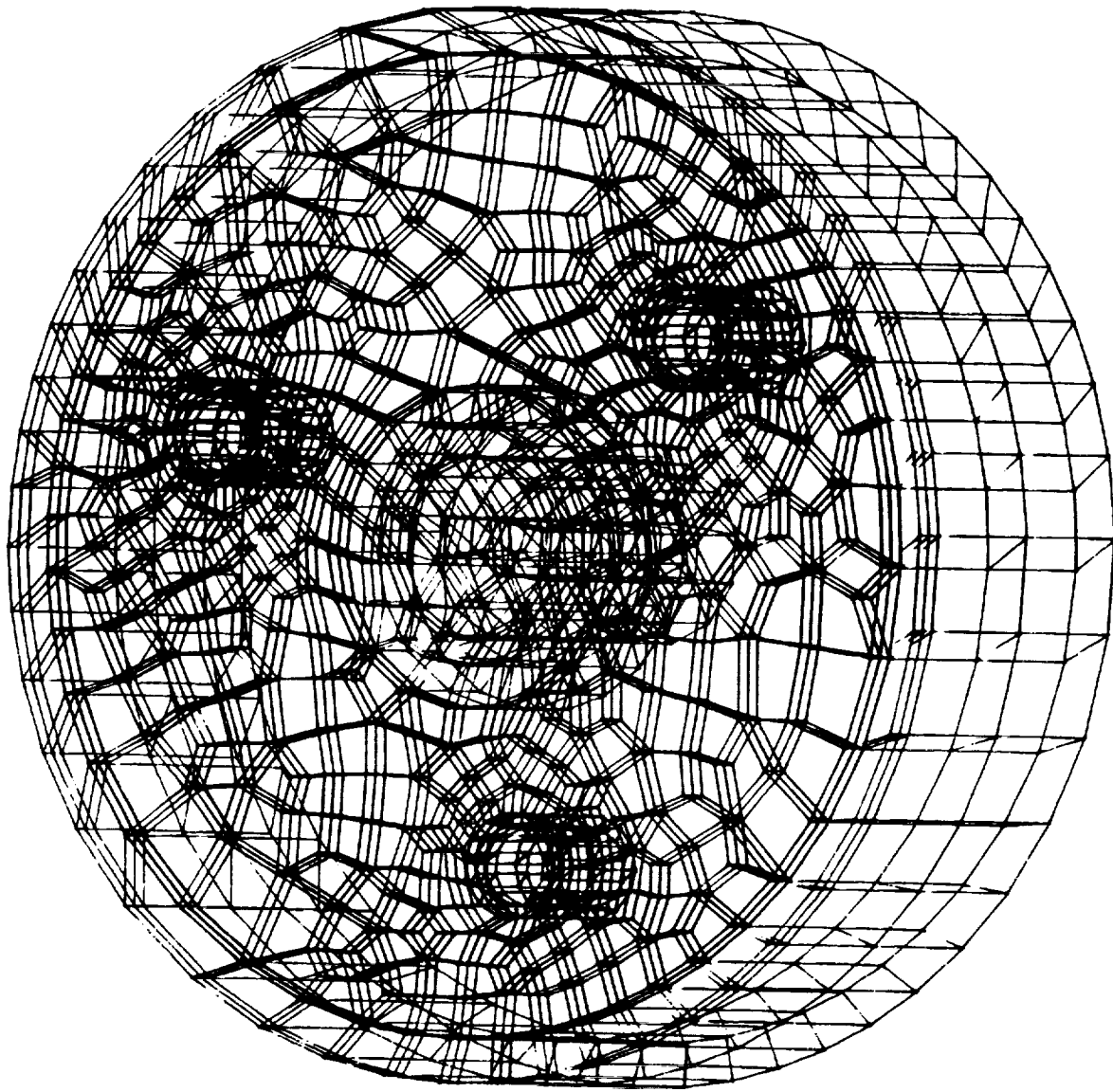


FIGURE 2

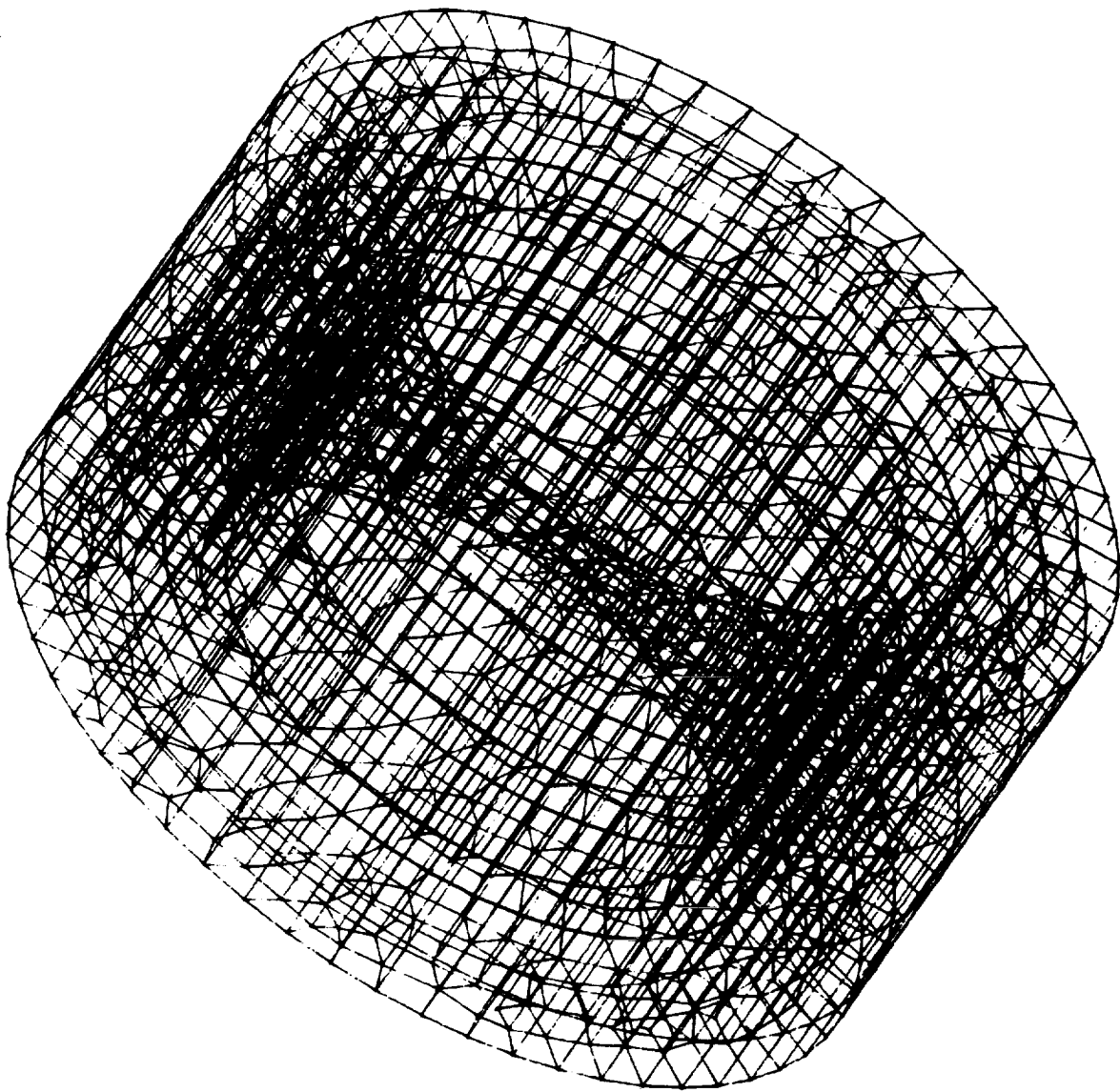


FIGURE 3

PC BOARD WT<sub>T</sub>, TANTALUM

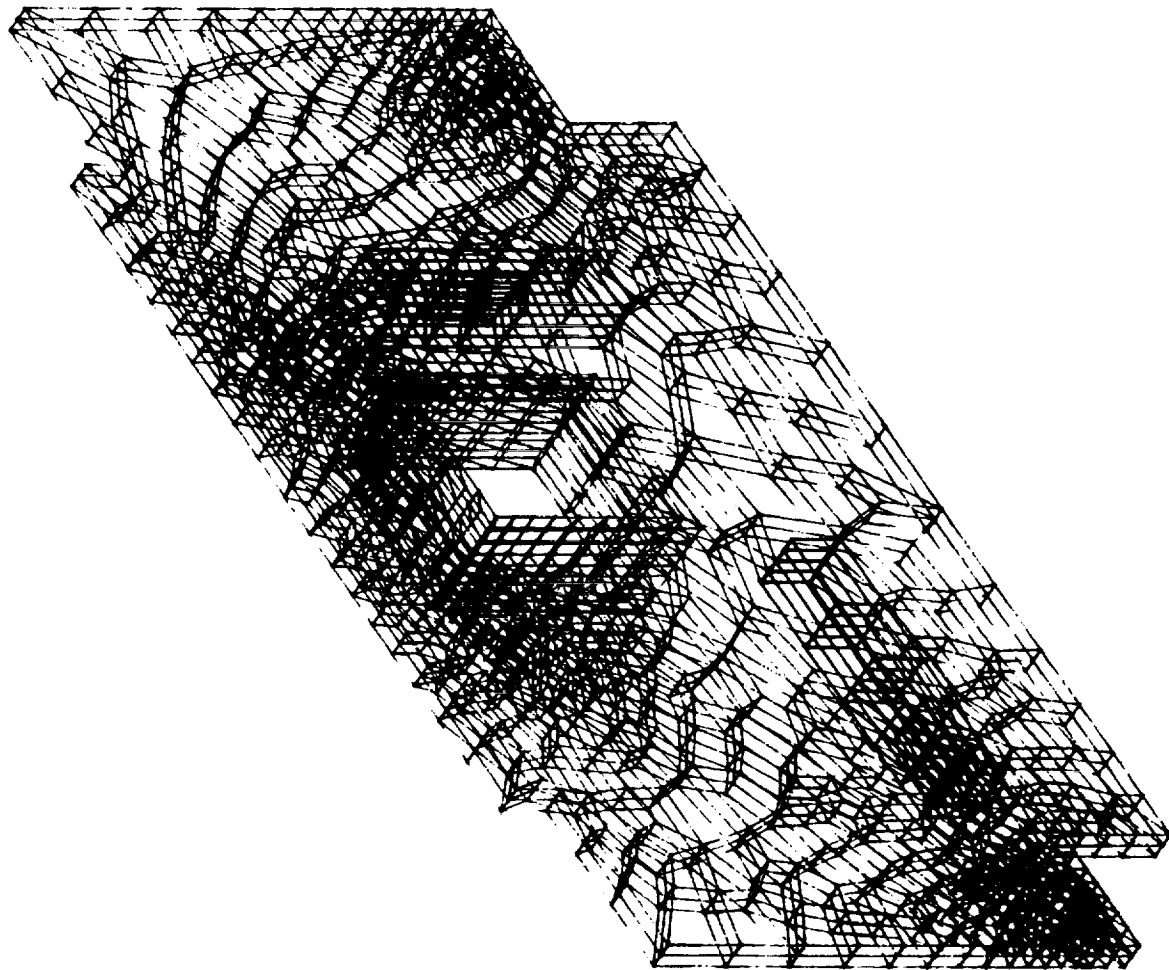
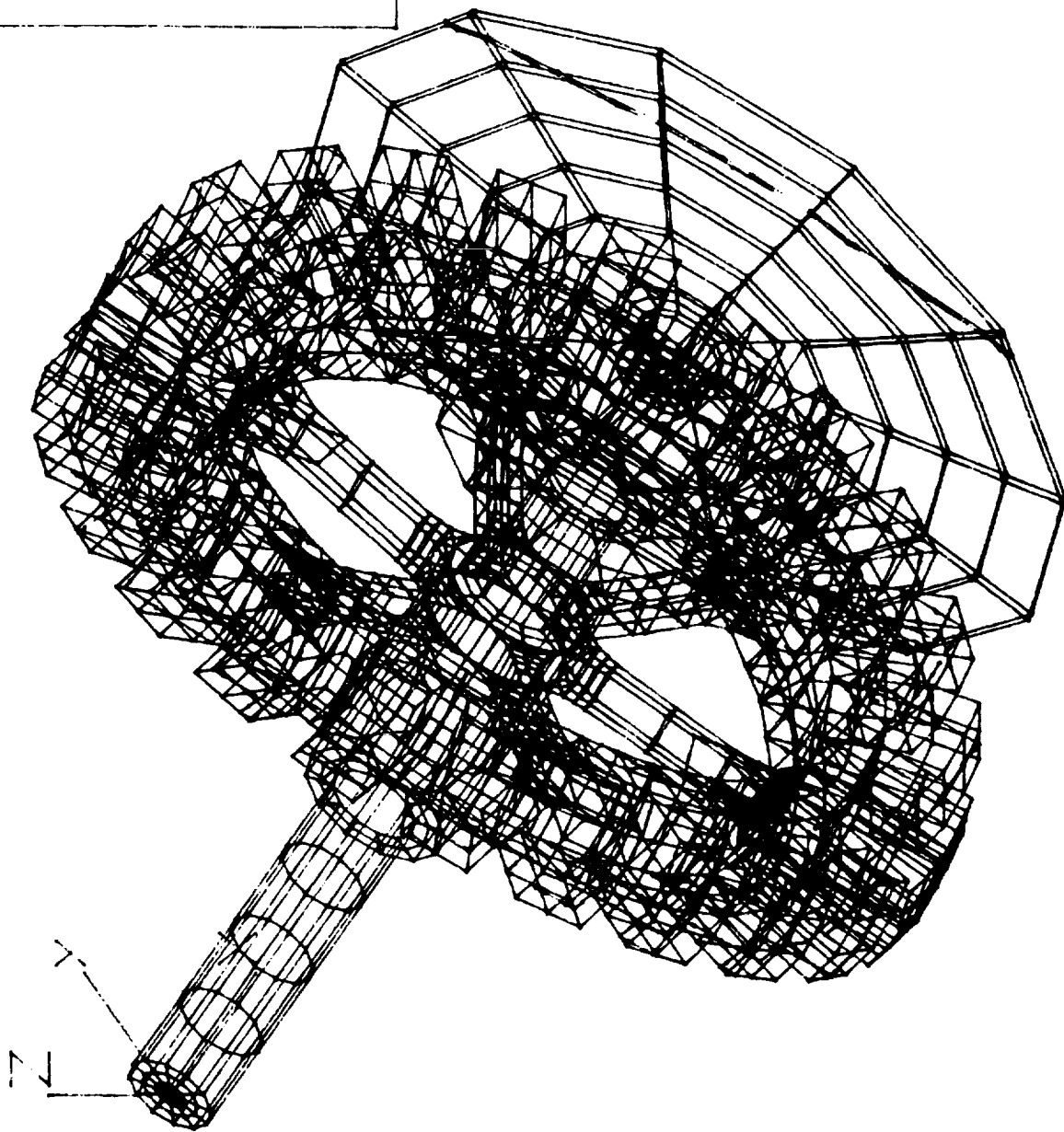


FIGURE 4

# ROTOR DISPLACEMENT FOR X DIRECTION VIBRATION



Displacement	
H	1.7e-08
—	1.5e-08
—	1.3e-08
—	1.1e-08
—	8.9e-09
—	6.7e-09
—	4.4e-09
L	2.2e-09
	0

FIGURE 5

# ROTOR STRESS (WITH DISPLACEMENT) FOR Y DIRECTION VIBRATION

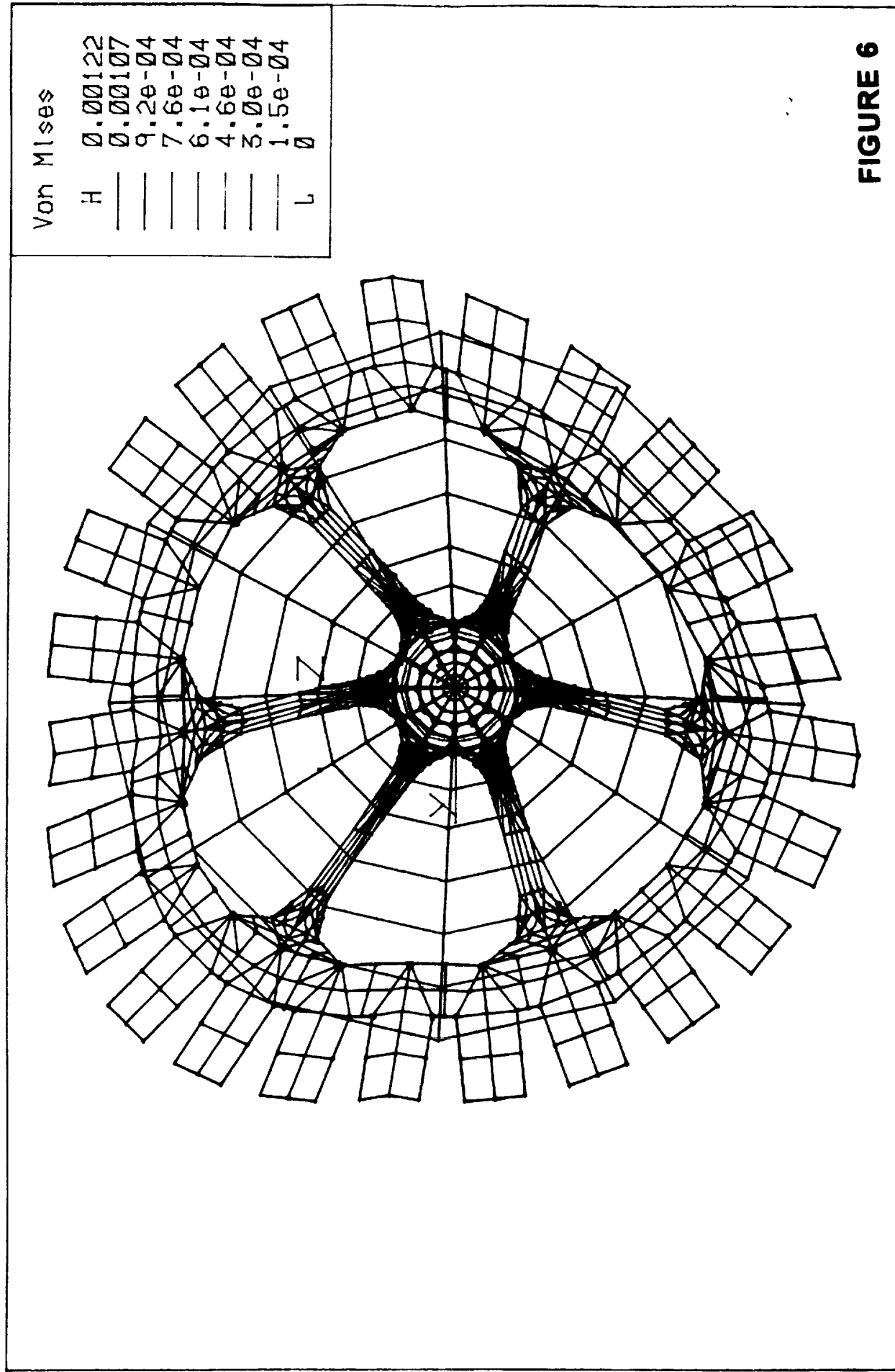


FIGURE 6

# BEARING SLEEVE STRESS (CUT AWAY)

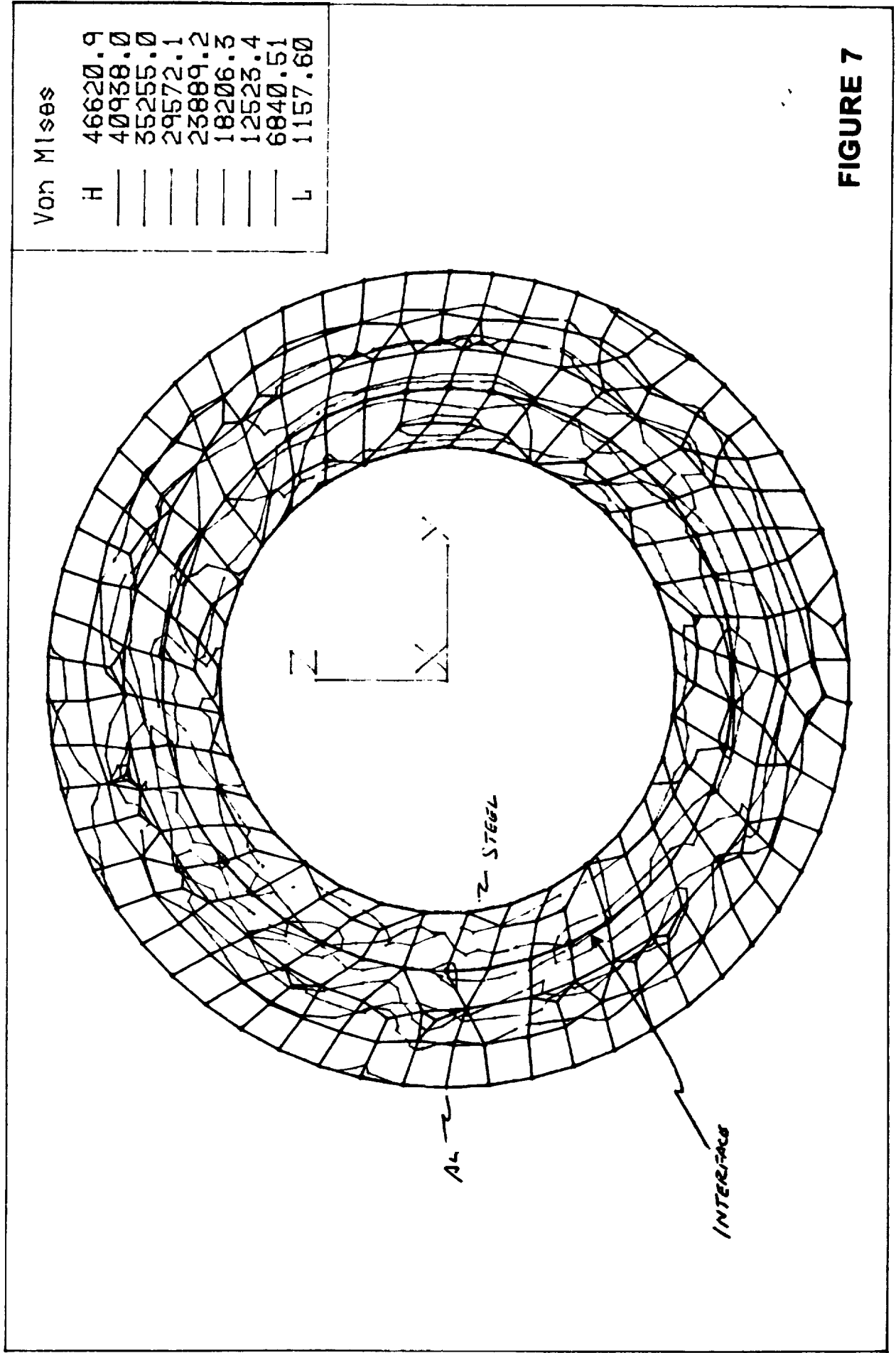


FIGURE 7

# HOUSING INSERT POCKET STRESS (ENLARGED)

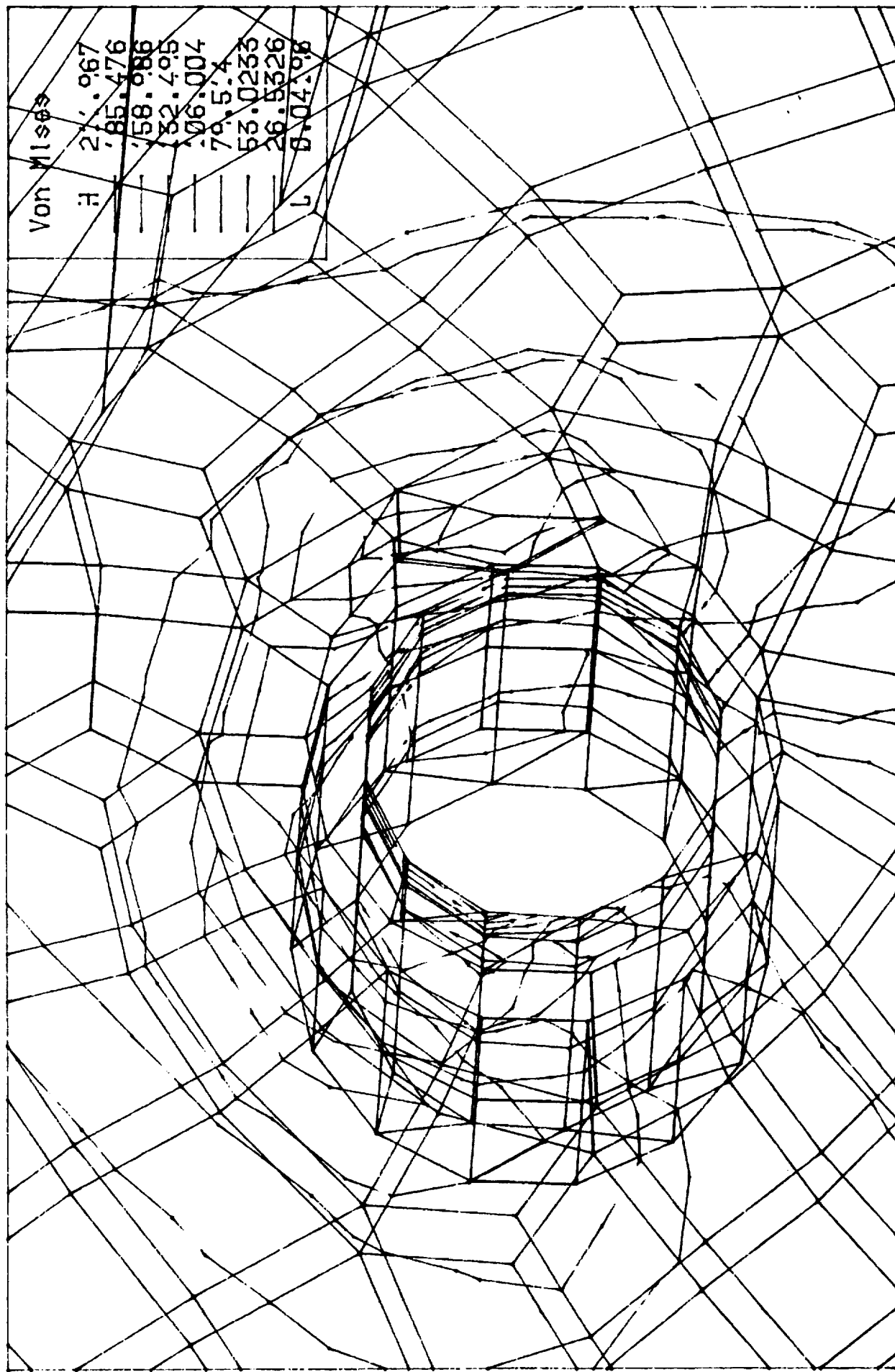


FIGURE 8

## HOUSING INSERT CONSTRAINTS

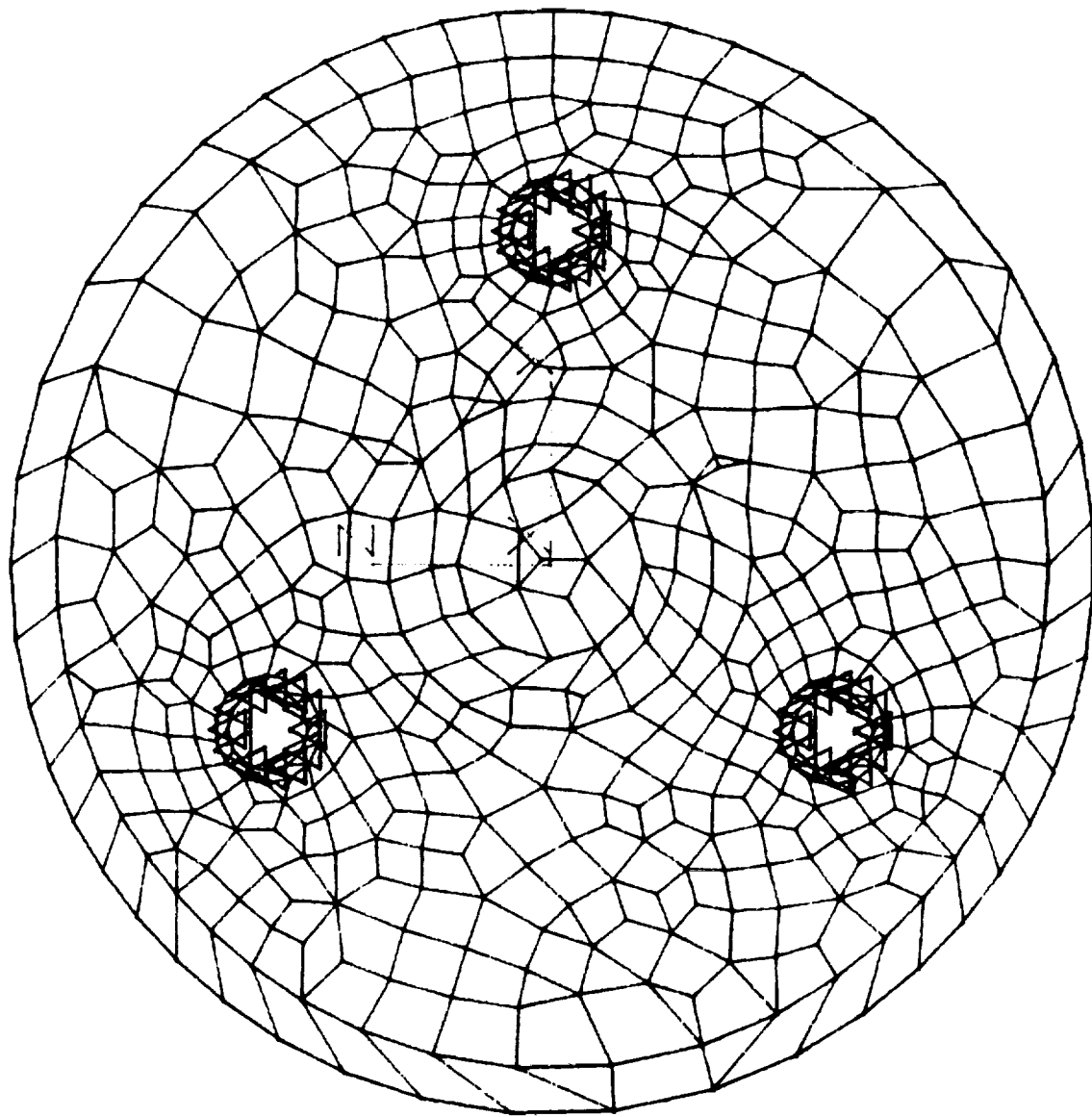
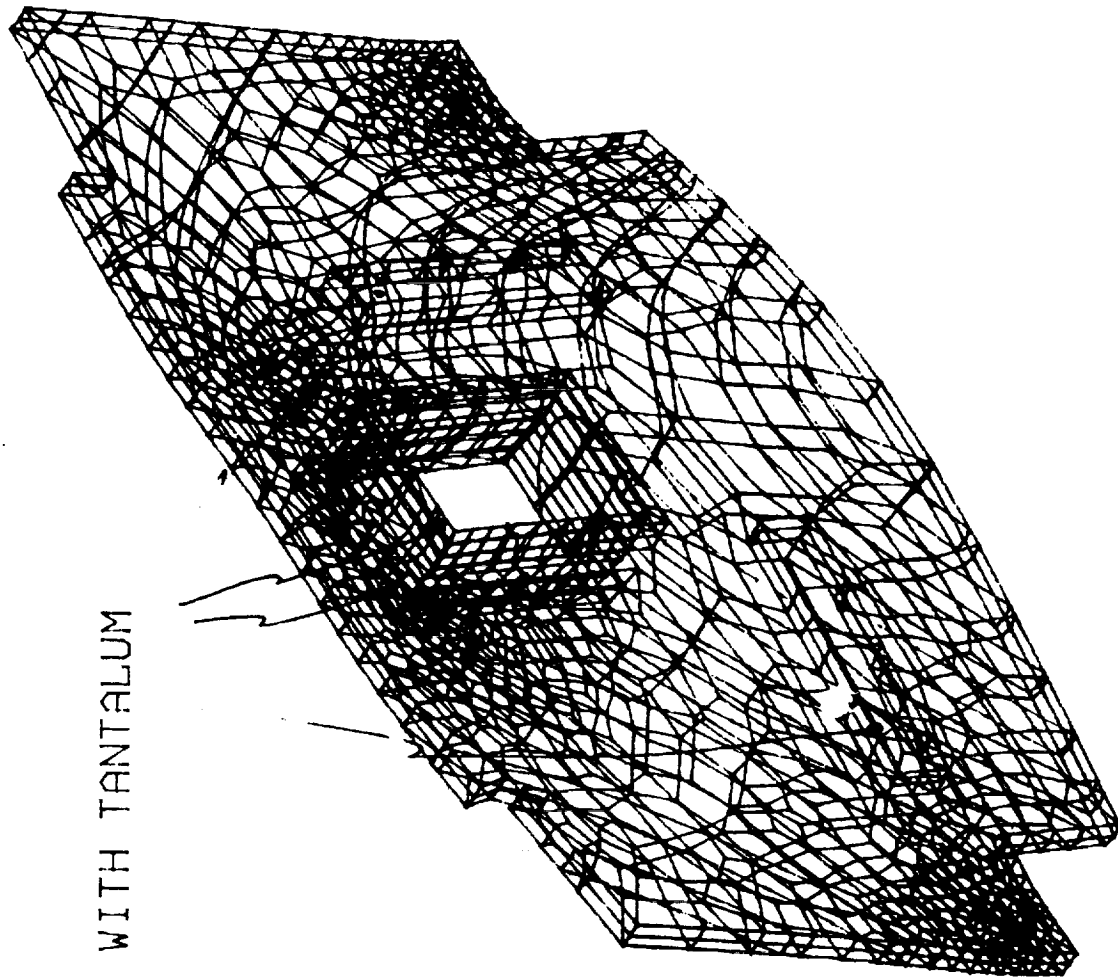


FIGURE 9

# PC BOARD DISPLACEMENT FOR X AXIS VIBRATION

SXI PC BOARD WITH TANTALUM



Displacement	
H	6.4e-06
---	5.6e-06
---	4.8e-06
---	4.0e-06
---	3.2e-06
---	2.4e-06
---	1.6e-06
L	8.0e-07

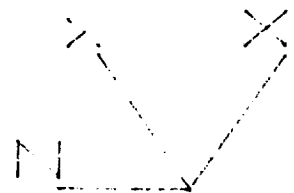
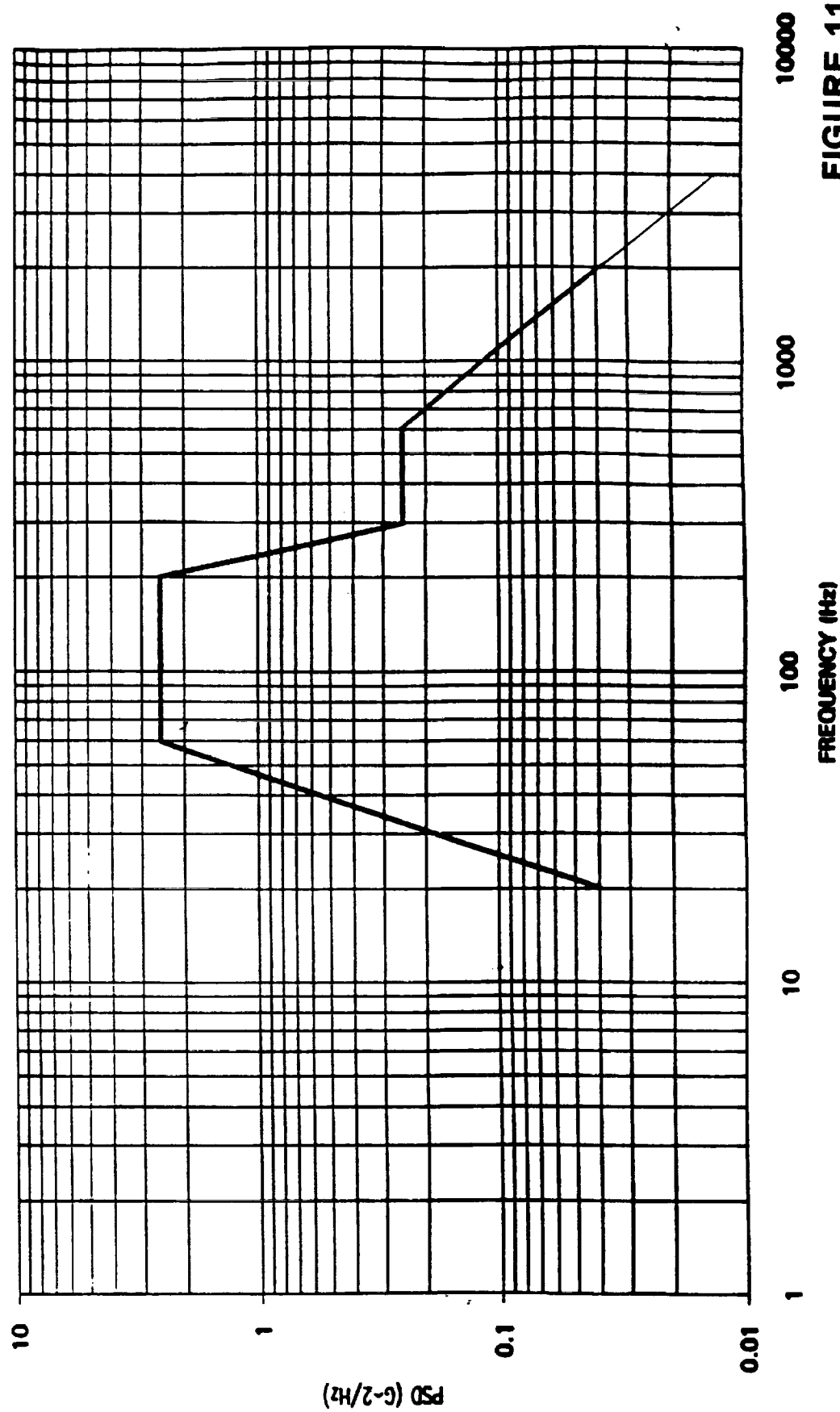


FIGURE 10

M021492.XLC

**SXI MOTOR RANDOM VIBRATION CRITERIA 2/14/94 26.1 Grms**



**FIGURE 11**

**ADDENDUM: Response to NASA 3/30/94 comments on stress analysis for the SXI motor.**

Additional analysis added static loads, combined loads and sine vibration to the existing random vibration analysis.

The stress and displacement calculations are performed by the ALGOR FEA program. The ALGOR program allows the excitation of static accelerations in each of three axis or combinations of these axis to be applied to the model. This feature was used to determine the stresses and displacements for the static and combined loads. The program also allows a single frequency at a given acceleration be applied to the model in any of three axis. This feature was used to apply the sinusoidal excitation to the models.

The models were created using the dimensions of the drawing and were decoded into 3 dimensional "bricks" for the finite element analysis.

The rotor and hub assembly was constructed with a manual mesh to control densities so that reasonable computer space was available for calculation. The model was constrained at the bearing surface which prevented rotational or translational motion. All vibration inputs were relative to this base.

The Housing was constrained at the inner surface of the three mounting holes. A dense weight was cantilevered off the outer bearing surface to produce moments which would be applied by the actual rotor and stator during vibrations and accelerations.

The PC board was constrained at the inner surface of the 4 mounting holes. The tantalum shields were mounted to the pc board and IC's as shown in the drawings.

A series of 4 Tables show the type excitation, stress, displacement, yield strength used for the analysis, Safety factor used, safety margin between stress produced and yield strength reduced by the safety factor. (ie (yield strength/safety factor)/stress induced:1)

The material properties are shown in Table II of the original report.

Not every combination of load or every type of axis excitation was calculated because inspection of the data shows that the device is clearly well within yield limits with large safety margins for the materials and configurations designed. E.G. 14.7 G's was used for every axis in the analysis and not reduced as it could have been for the other axes. The displacements seen will be well clear of hitting other adjacent structures. In addition, the motor/encoder will undergo vibration testing.

# SXI STRESS ANALYSIS

Component

Rotae, motor

Comments:

$$R_n = 3 * \left( \frac{1}{2} * 1 + 1232 * .08 \right)^{\frac{1}{2}} = 37.4$$

Type excitation	Stress	Disp	Yield	Safety F	Safety M	Pit
Static, 14.76's, X axis	595 Psi	2.7E-5 in	2.45E5 Psi	1.25	325:1	Fig 1A
Static, 14.76's, Y axis	422 Psi	1.7E-5	"	"	464:1	
Combined $R_n + S_n = 52.14$ $S_y = S_o = 14.76$	2169	2.4E-4	"	"	90:1	Fig 2A
Sine, X axis, 14.76e 50 Hz	.11	1.1E-8	"	"	1.78E6:1	
Random, X axis	.137	1.7E-8	"	"	1.5E5	Fig 5
Random, Y axis	1442	1.3E-4	"	"	139.4:1	Fig 6

# SXI STRESS ANALYSIS

Component

ROTOR, ENVELOPE

Comments:

Type excitation	Stress	Disp	Yield	Safety F	Safety M	Plt
Static, 14.76's, X AXIS	100 PSI	4.6E-5 INCH	3.6E4	1.25	288.1	FIG 1A
Static, 14.76's, Y AXIS	< 35 PSI	7.1E-5	"	"	> 1028:1	
Combined $R_x + S_x = 52.14$ $S_y + S_z = 14.74$	542	2.3E-4	"	"	53:1	FIG 2A
RANDOM, X	< .187	< 1.7E-8	"	"	> 15E5:1	FIG 5
RANDOM, Y	< 1442	< 1.3E-4	"	"	> 139:1	FIG 6

# SXI STRESS ANALYSIS

Component

Drilling

Comments:

$$R_z = 3 \times \left( \frac{1}{2} \times 1 + 2509 \times .015 \right)^{1/2}$$

Type excitation	Stress	Disp	Yield	Safety F	Safety M	Pit
STATIC, X A1.3	197 Psi	8.3E-6	4.0E4 Psi	1.25	162:1	F19 3A
Combined $R_z + S_z = 37.7$ $S_y = S_z = 14.7$	889	4.1E-5	"	"	36:1	F14 4A
Random, X, F14 "	2.11	7.8E-5	"	"	133:1	F14 8
Random, Y, F14 "	1.2	4.5E-7	"	"	2,3E4:1	

# SXI STRESS ANALYSIS

Component

PC Board, Lg

Comments:

$$R_x = 3 * (\pi/2 * 1 * 1240 * .08)^{1/2}$$

Type excitation	Stress	Disp	Yield	Safety F	Safety M	Pit
Static, 14.76's, Xaxis	371 Psi	1.9E-4 in/in	3.5E4 Psi	1.25	75:1	Fig 5A
Static, 14.76's, Yaxis	48.7	1.9E-6	"	"	574:1	
Combined Sx + Rx = 52.1 Sy - Sz = 14.7	1321	6.9E-4	"	"	21:1	
Sine, X, 14.76 CSDHz	384	2.0E-4	"	"	73:1	
Sine, X, 56 C 100 Hz	132	7.1E-5	"	"	265:1	
Random, X, Fig 11	11.9	6.4E-6	"	"	2353:1	Fig 10
Random, Y, Fig 11	11.4	6.4E-6	"	"	2432:1	

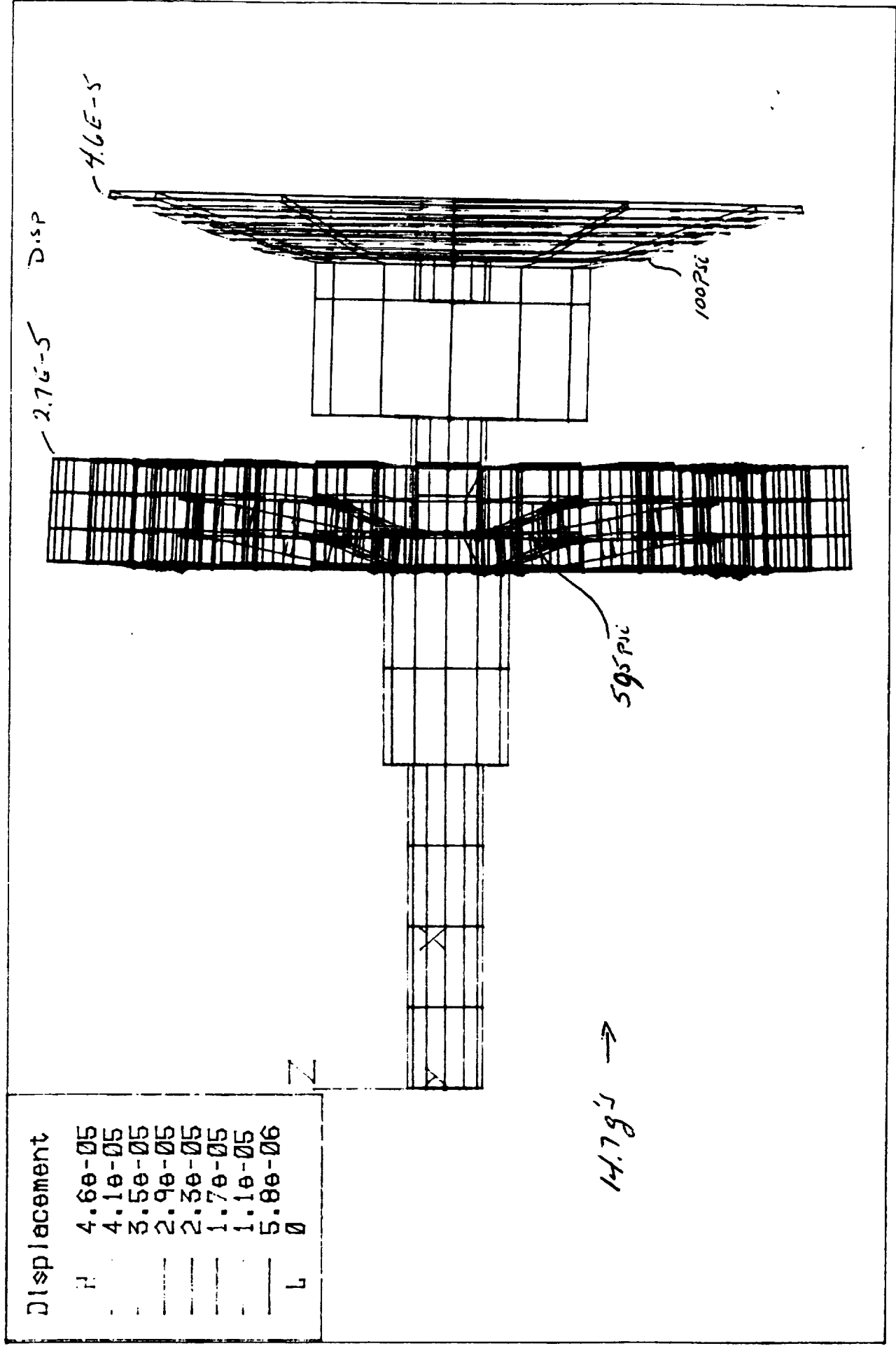
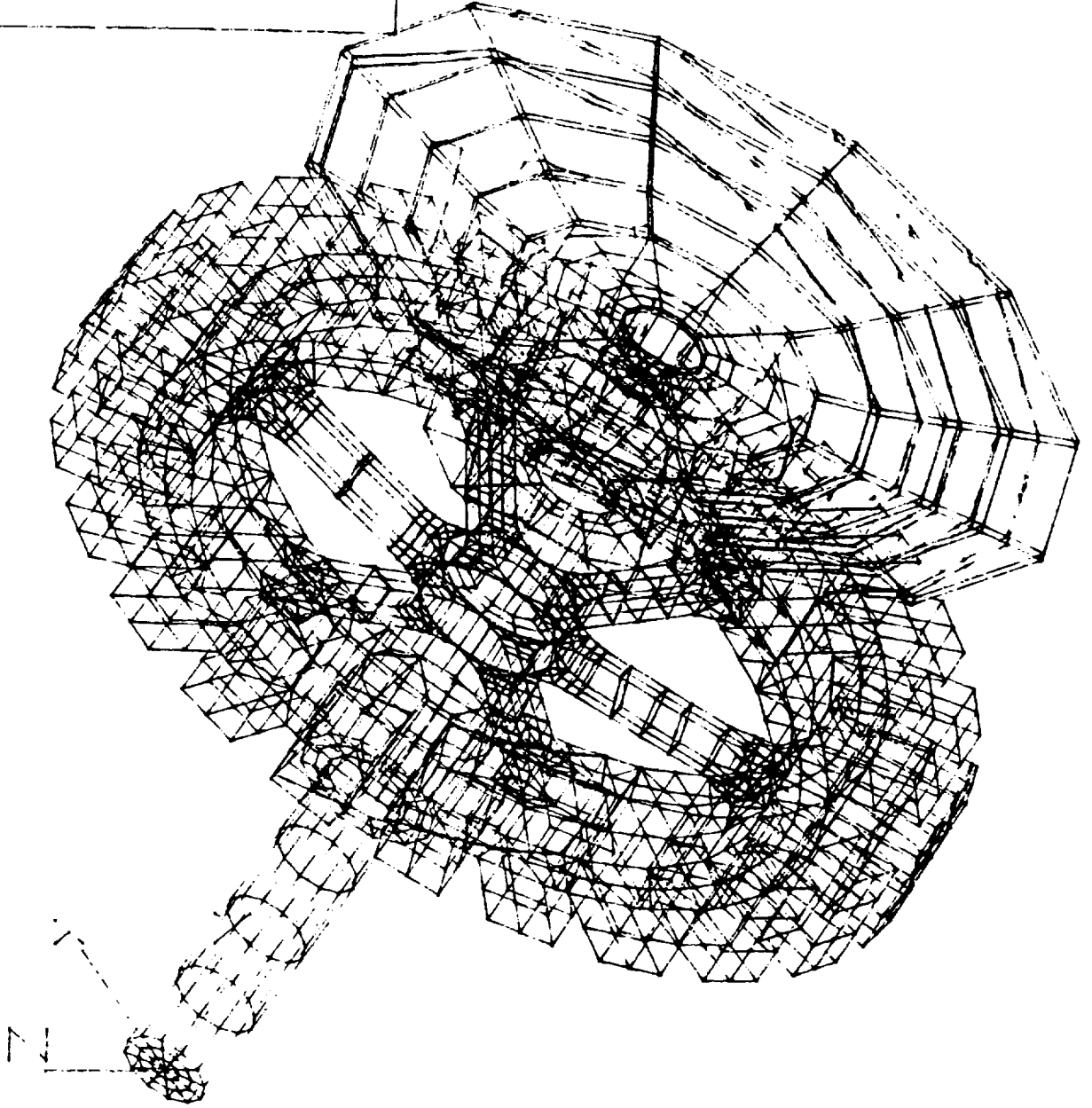
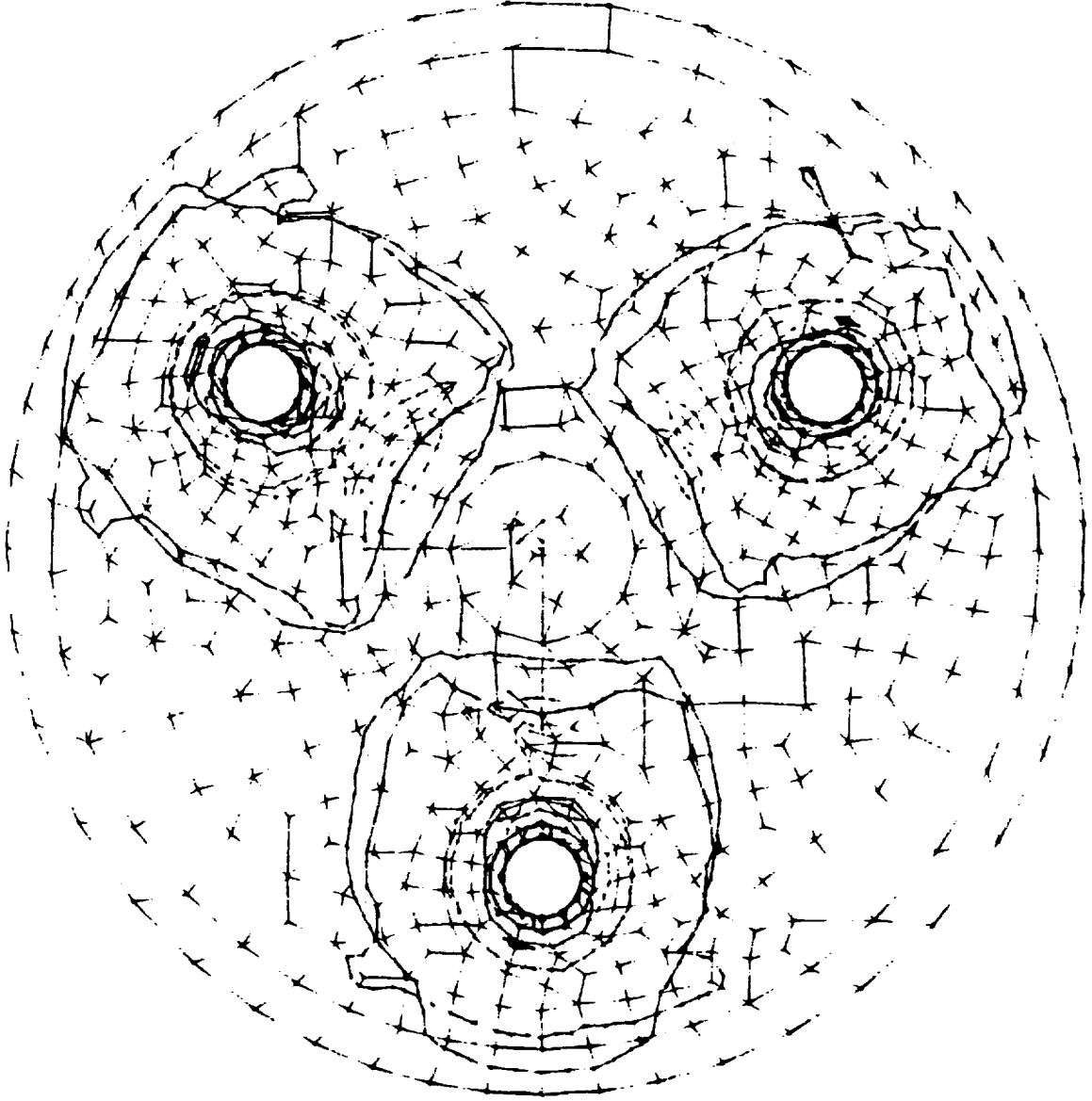


Fig 1A

Displacement	
1	2.3e-04
2	2.0e-04
3	1.7e-04
4	1.4e-04
5	1.1e-04
6	8.9e-05
7	5.9e-05
8	2.9e-05
9	0



Von Mises	
1	197.915
2	173.209
3	148.504
4	123.798
5	99.0934
6	74.3879
7	49.6824
8	24.9769
9	0.27150



Von Mises	
$\sigma_H$	889.366
	778.313
	667.260
	556.207
	445.153
	334.100
	223.047
	111.994
L	0.94095

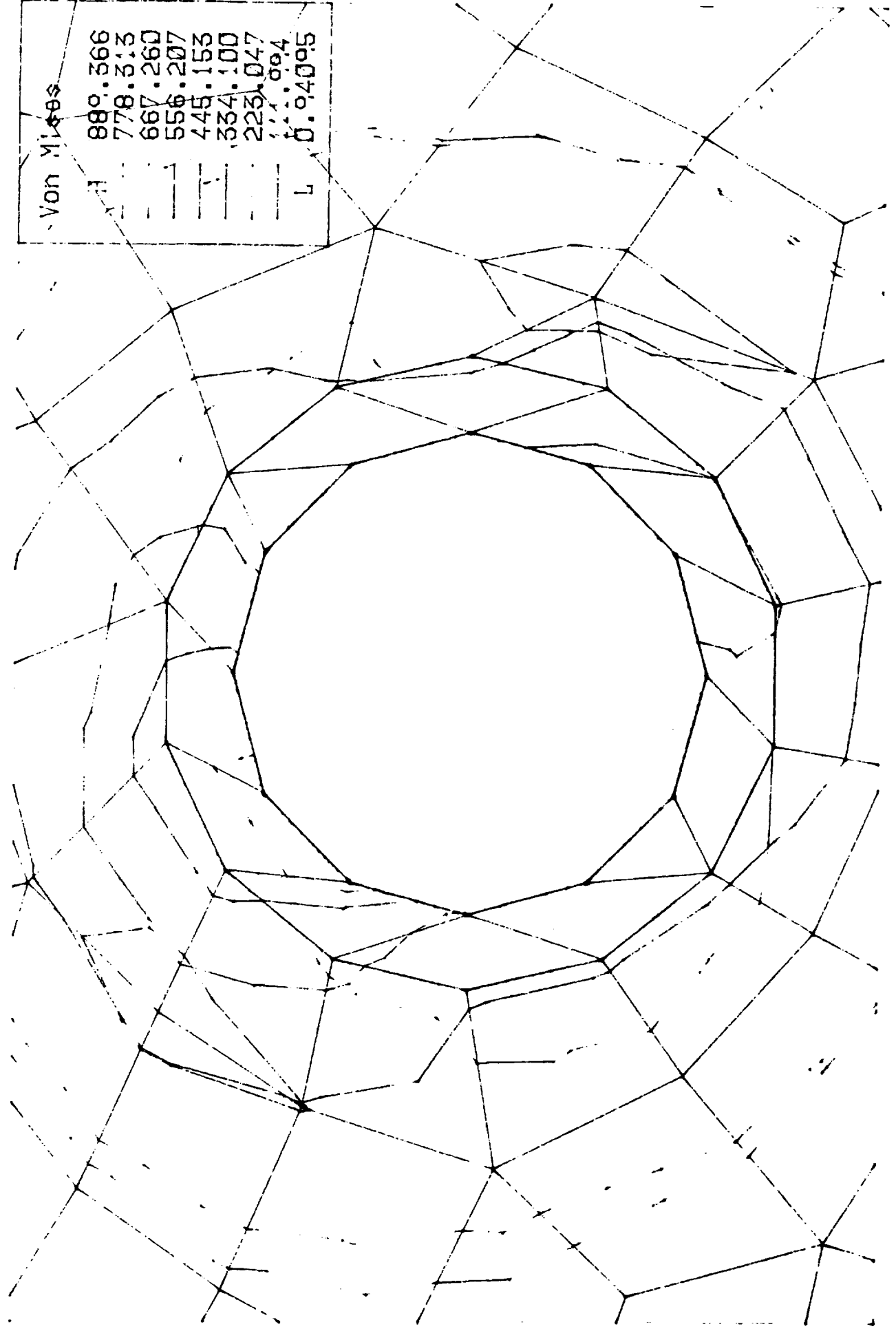


Fig. 4A

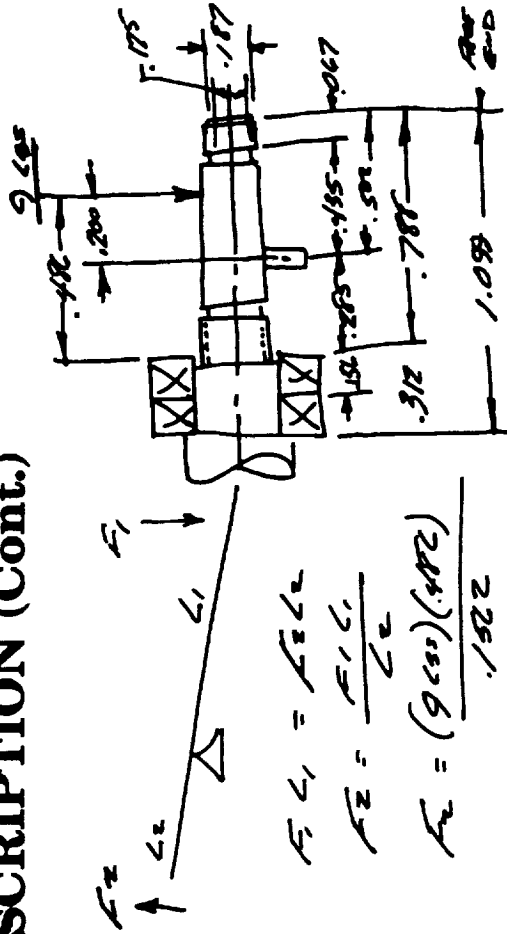
# Von Mises

H	371.041
	324.682
	278.323
	231.964
	185.605
	139.246
	92.8872
	46.5281
L	0.16905



# ● DESIGN DESCRIPTION (Cont.)

- MOTOR



$$F_1 L_1 = F_2 L_2$$

$$\frac{F_1}{F_2} = \frac{L_2}{L_1}$$

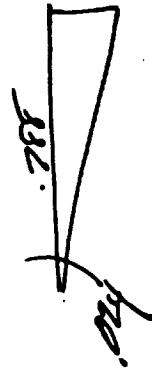
$$F_2 = \frac{(286)(1.87)}{1.87}$$

$$\underline{\underline{286}}$$

$$(286) (.000478 \text{ in/in}) = 1.36 \times 10^{-4}$$



$$\frac{1.36 \times 10^{-4}}{.912} = .024$$



$$5m .024 \frac{1}{787} = .0033$$

$$.0033 \text{ in/in}$$

$$.0055 \text{ in/in}$$

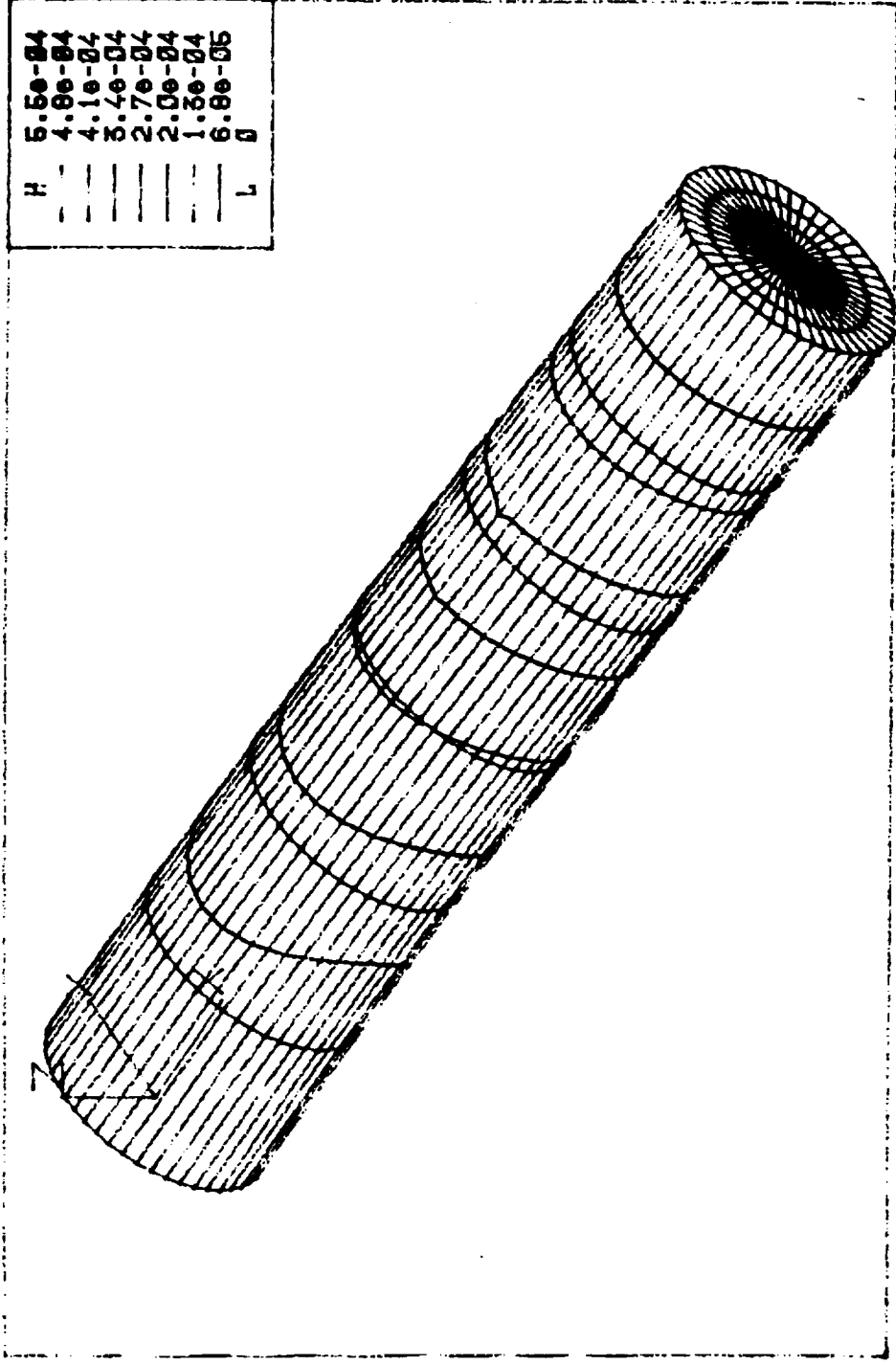
$$.0088 \text{ Total for end}$$

$$\underline{\underline{1.7 \times}}$$

SHAFT DEFLECTION

● DESIGN DESCRIPTION (Cont.)

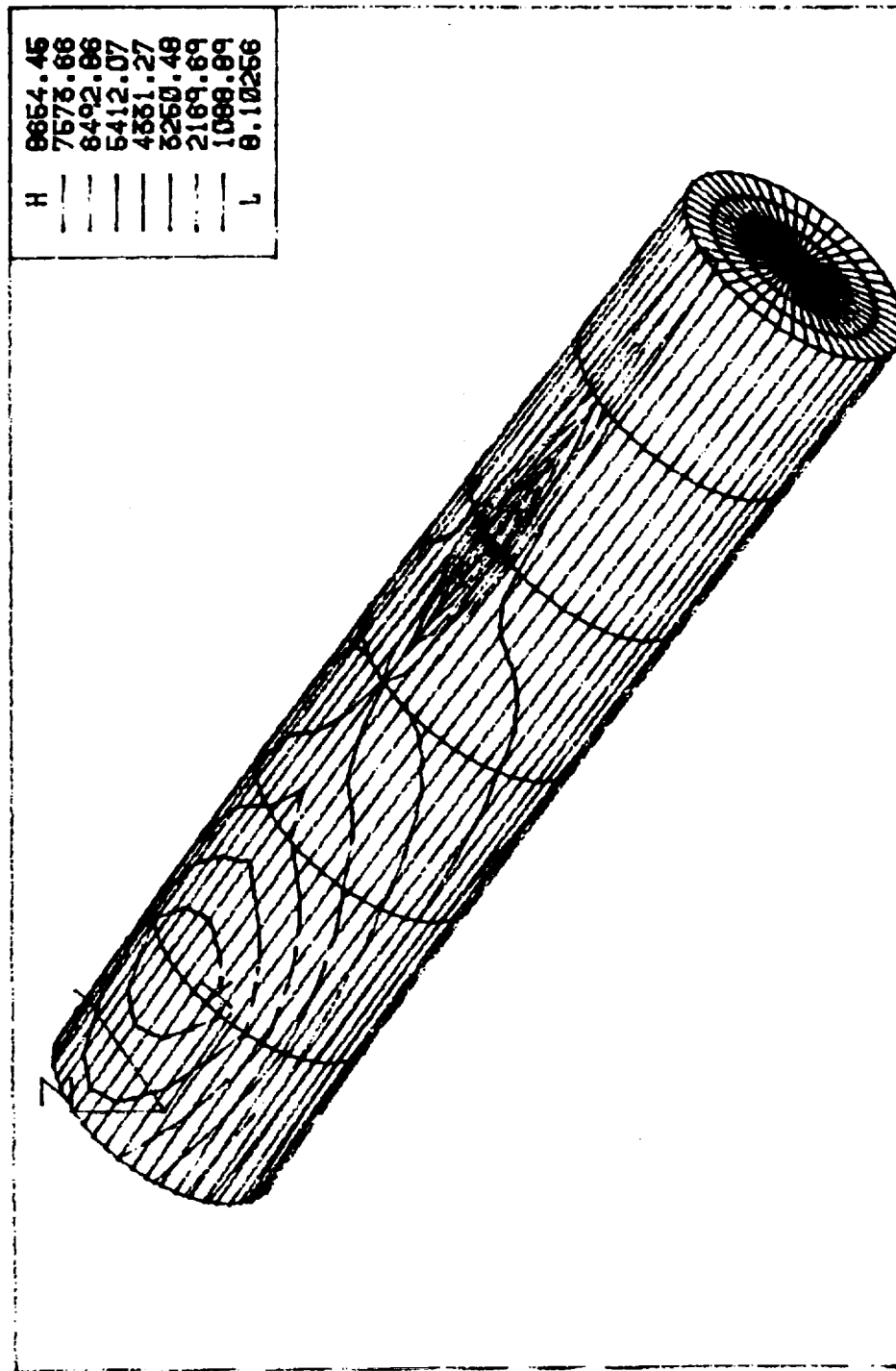
- MOTOR



SHAFT DEFLECTION

# ● DESIGN DESCRIPTION (Cont.)

- MOTOR



SHAFT STRESS